UNIVERSITÉ DE MONTRÉAL

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AN INTERACTIVE-GRAPHIC SYSTEM FOR STRATEGIC TRANSPORTATION ANALYSIS AT THE NATIONAL AND REGIONAL LEVELS

by

Michael Florian, Teodor Gabriel Crainic,
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ABSTRACT

STAN is an interactive graphic system for national or regional strategic planning of multimode multiproduct transportation systems. We briefly describe the general concepts underlying the system, the data base structure, the assignment procedures and the results. We also give some examples of dialogs and outputs.

KEY WORDS: Interactive graphic system, Multimode multiproduct assignment, Strategic planning.

RESUME

STAN est un logiciel interactif-graphique pour la planification nationale ou régionale des réseaux de transport multiproduit multimode. Nous décrivons brièvement les concepts généraux sous-jacents au système, la structure de la base de données, les procédures d'affectation et les résultats. Nous incluons également quelques examples de dialogues et de sorties graphiques.

MOTS CLES: Logiciel interactif-graphique, Affectation multimode multiproduit, Planification stratégique.

AN OVERVIEW OF THE STAN SYSTEM

1. Introduction

STAN is an interactive graphic multi-product multi-mode method for national or regional strategic planning of freight transportation. The strategic level of planning implies a medium to long term time horizon and a rather aggregate level of detail for the representation of the transport services provided. The contemplated alternatives represent usually anticipated (or predicted) changes in the origin to destination demands for the products considered and major changes to the transportation infrastructure. At the strategic level of planning, the aim is to obtain an overall estimation of the movements of freight of most (or all) products by most (or all) of the modes available: thus tactical decisions (such as when to schedule the trains that are operated) are not considered at this level.

A typical use of STAN is the comparison and evaluation of alternatives. Usually, an existing situation is described by one of the scenarios of the data base (base scenario). A simulation of the freight flows is carried out. Future situations are described by other scenarios which are constructed and contained in the data base. The simulation of freight flows are carried out on these scenarios as well. Then flows, link costs and delays, intermodal shipments and other performance indicators may be compared to those of the base scenario in order to carry out cost/benefit analyses.

STAN is the first interactive-graphic method which was designed for strategic planning of freight flows at the national or regional level. It allows the planner to engage in the planning process by using terminology that he is familiar with and obviates data processing type tasks. Once the data base is set up, the planner needs not know or concern himself with the technical details of computer programming or computer systems. It also permits him the instantaneous visualization of input data, results of computations and information retrieved from the data base, all in graphic or list form. In the following, we describe the main features of this system.

Although STAN is specifically designed for freight transportation, it is based to a large extent on the design of EMME/2 [2,9], which is an interactive/graphic multi-mode method for urban and regional planning for the transportation of persons. In particular, the user interface is very similar to that used in EMME/2 [1].

2. General Concepts That Underly The Design Of STAN

In STAN, the data that may be entered, modified and used for calculations falls into three main categories: networks, matrices and functions. Diagram I.1 below gives a schematic representation of the STAN data base, and is helpful in clarifying the descriptions that follow.

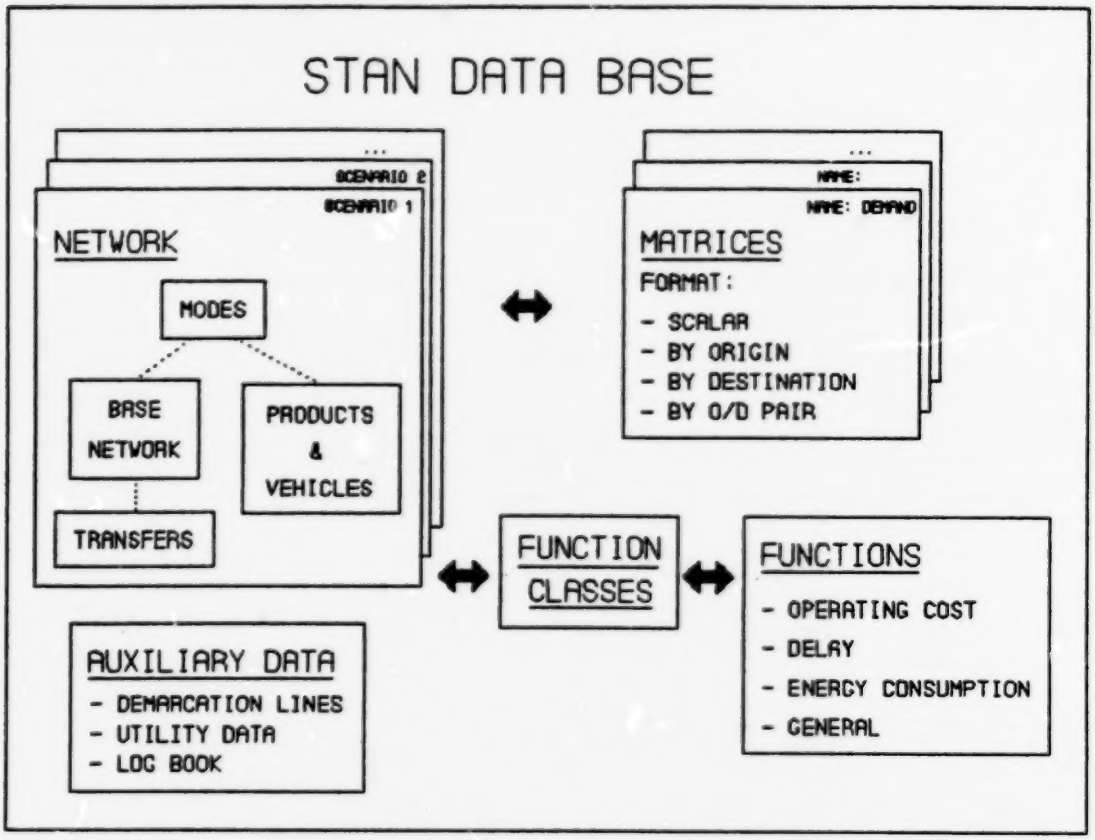


Diagram I.1

The network data may be entered, modified and displayed by using the Network Editor. The Matrix Editor performs the same operations for **matrices**, and provides as well facilities for matrix calculations and matrix balancing. All the relevant **function classes** and functions are entered and evaluated by the Function Editor. The STAN data base may also contain **demarcation lines**, utility data and a **log book**, which we refer to as the **auxiliary data**. Demarcation Lines may be superimposed on graphic displays to make them more readable. Utility data contain titles, module parameters, predefined windows,... A Log Book keeps track of the use made of the various STAN modules in manipulating the data base.

Brief descriptions of the **Networks**, **Matrices** and **Functions** that may be entered and manipulated by STAN are given in the following sections.

2.1 The Networks

The transportation infrastructure that spans the region studied is represented by a multimodal network. The flows that can occur over this transportation network are described by specifying the products and the modes used for their transport. A network scenario is described by the modes, products, vehicles, base network and transfers. Any of this data may be modified, at any time, provided that the hierarchy of the data structure is respected, as shown in Diagram I.2

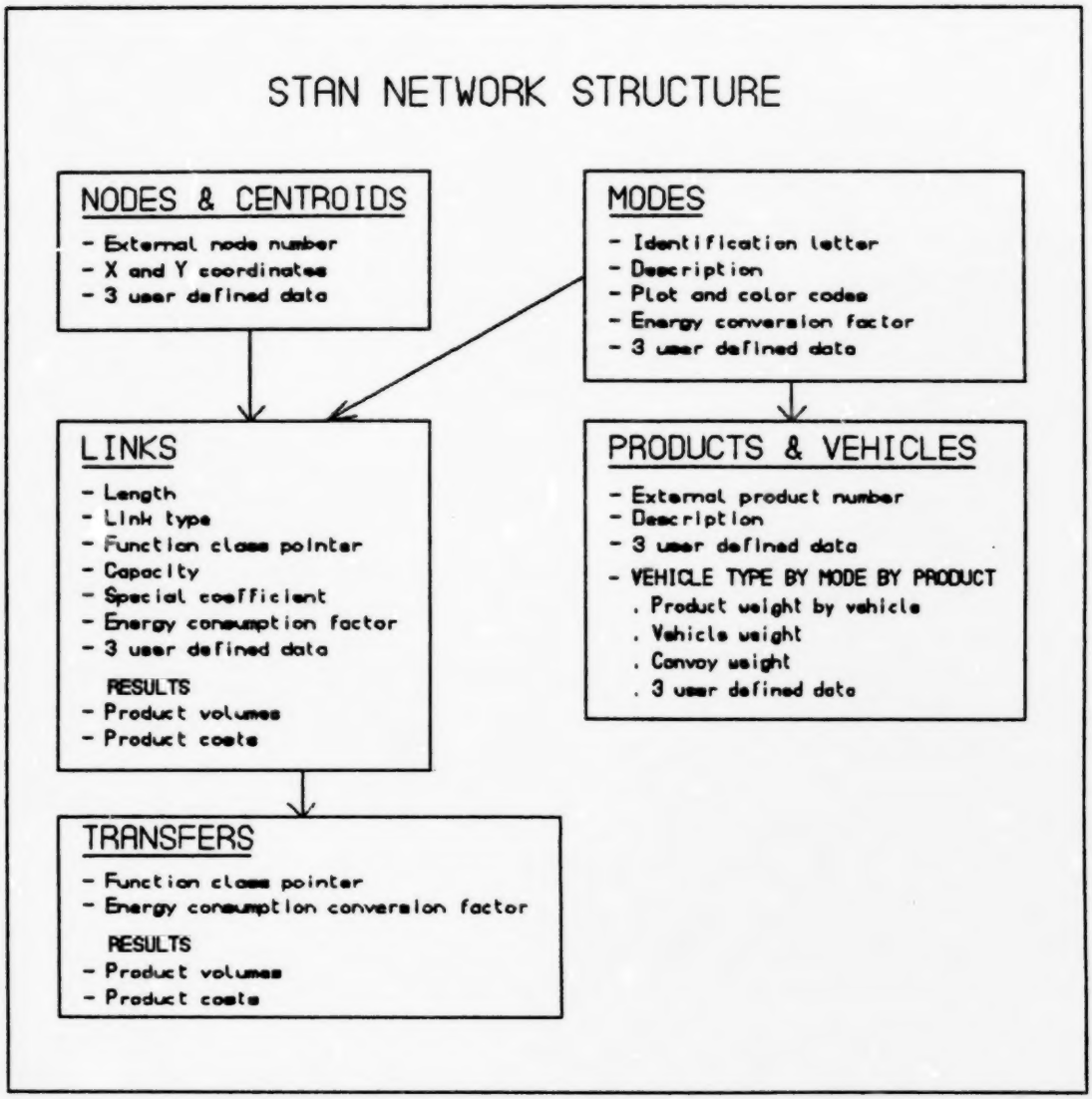


Diagram I.2

The **base network** is defined by the list of all the nodes and all the links between those nodes. In STAN parallel links are allowed between two nodes with the convention that a single mode is allowed on a given link. A path may contain successive links of different modes only if transfers are specified between them. A **transfer** is defined at a node, as a sequence from the mode of the incoming link, via the node, to the mode of the outgoing link. Thus, **transfers** represent intermodal transhipments at nodes.

For each product, a vehicle type is specified for each mode. A **vehicle** is described by its weight, by the weight it can transport and by an optional convoy weight (used for instance, to specify train length). The number of vehicle types equals the number of products multiplied by the number of permitted modes.

The user may specify up to three additional data elements for each **mode, product, vehicle, node** and **link**. Such **user data** may be observed flows or any associated data that the planner intends to use in subsequent analyses.

Each complete network data set (modes, products, vehicles, base network, transfers) makes up a **scenario.** The base period is one of these scenarios. The user may define a new scenario, by duplicating the data present in an existing scenario and by making the appropriate changes in any one of the network data components. All these manipulations may be performed interactively, graphically when appropriate. In STAN, the network data that corresponds to a **base period** is not conceptually different from data of contemplated scenarios.

2.2 The Matrices

The **matrices** that are handled in STAN may be full matrices, origin or destination vectors or scalars. These may contain various data related to the zone subdivision of the area studied, such as origin/destination demand matrices, production by origin and attraction by destination. A matrix may be both an input to or an output from a computational procedure.

The matrix editor, which is the same as that of EMME/2, has been designed to permit the user to choose a matrix format that avoids duplication of data in the data base. For instance, if a full matrix has the same value in all its cells, then the user may specify only a scalar matrix and its value. The matrix editor will then use only the space required to keep the scalar, until a full matrix is requested in a STAN module. Then it will automatically expand the scalar value to a full matrix with that value in all of its cells for the execution of that module. The same concept applies to given values for origins or destinations.

The matrix editor does not define any matrices by default. The definition of a matrix and its contents are left to the user. Thus, if an assignment

routine expects the availability of origin/destination matrices, the user defines these matrices and ensures that they contain the correct data. This provides great flexibility in evaluating a given scenario with different O/D matrices.

Any network scenario created by the Network Editor may be used with any of the matrices present in the data base. The user identifies the relevant matrices that he wishes to use with a given scenario. The Matrix Editor of STAN also contains matrix balancing procedures in two and three dimensions. Their judicious use, with the appropriate matrices, permits a user to scale matrices or to implement some versions of classical spatial interaction (trip distribution) models.

Whenever the matrix editor expects a zone number, a zone group can be specified, indicating that the operation applies to all zones within the group. A zone group is a set of zones. A set of zone groups that includes all the zones is called an ensemble. Within an ensemble, a zone may be in only one group. The user of STAN may specify up to 26 ensembles, each containing up to 100 zone groups. The advantage of using zone groups is that selection of subsets of zones may be accomplished efficiently, which is useful in many applications.

The Matrix Editor includes a module which permits the user to perform matrix calculations. The user specifies the operations that he wants to perform as an algebraic expression. Such algebraic expressions may be stated by choosing from 16 logical and algebraic operands and 9 intrinsic functions. The variables that may be used in these expressions are the matrices of the STAN data bank, centroid numbers and zone groups.

2.3 The Functions

The **functions** that are used in STAN are subdivised into three types: operating cost functions, time delay functions and energy consumption functions. These functions may be specified for links and for transfers.

These functions are not part of the code and have to be specified by the user as algebraic expressions. When required, a function is evaluated with data that corresponds to the variables specified by the user in the algebraic expression that defines it.

A **function class** is an index that associates to a link (transfer) a triplet of functions: an operating cost, a time delay and an energy consumption function. Function classes are an efficient and compact way to associate functions to links and transfers. Several links (transfers) may share the same function class.

In addition to the types of functions described above, the user is free to define and display functions that are not employed in any of the standard calculations of STAN.

2.4 Assignment Procedures

The most general **assignment procedure** provided by STAN is a multimode multiproduct assignment method which minimizes the total cost of shipping the products considered, from origins to destinations, via the permitted modes.

For each product, a subset of modes, which are permitted for a given assignment may be specified. Moreover, the O/D demand matrix of a product may be decomposed and a similar subset of modes may be defined for each resulting O/D matrix. This mechanism allows the introduction of predefined mode choices into the STAN system. It is always possible to assign all the products to all the modes, if desired.

The assignment does not permit explicit capacities on the network. Thus, when the services of certain modes are subject to capacity restrictions (e.g., rail, ports), these may be modeled as congestion and penalty functions, usually integrated into the delay cost fuctions.

The assignment procedure may be carried out by using delay functions, in units of time, cost functions in currency units, energy costs in the appropriated units or generalized costs (weighted combinations of time delays, operating costs and energy costs). The interaction between the costs of different products on different modes is considered explicitly in the assignment procedure of STAN.

Another computational algorithm that will be provided by the STAN system is a multiproduct multimode maximum flow method. This facility allows the evaluation of the maximal amounts of certain commodities that can be transported with the existing transportation infrastructure and thus, may be very useful when considering major changes in the demand.

2.5 The Results

STAN permits the user to obtain a wide variety of **results** in interactive graphic form and/or as a printed output. The main feature of the results is the possibility of interactive comparison of scenarios with graphical displays. While the main results pertaining to comparison of scenarios are related to flows and costs, a wide variety of other results may be obtained using the user defined data.

Worthy of emphasis is that, unlike a "batch" code where each successful execution terminates with a particular set of results, an interactive graphic system allows the user to obtain results of different types during a particular session. The notion of "result" is thus different from that of a batch code and may be considered to consist of the entire gamut of displays, results of computational procedures, data bank queries and scenario comparisons.

2.6 Auxiliary Data

The Auxiliary Data consists of **demarcation lines**, **log book** and **utility data.**

The user may define **Demarcation Lines** that may be superimposed on a graphical output. A demarcation line may identify geographical characteristics of the area such as rivers or mountains, or certain regions of the country such as provinces, states, etc... .

A **Log Book** keeps record of the identity of the user and of the modules and elements of the data base used during all STAN sessions.

Utility Data refers to certain data which are related to the use of STAN. These data may be transfered from one STAN data base to another to facilitate the construction of new data bases.

1. STAN The Computer Based System

STAN has been coded in standard ANSI Fortran 77 and has been designed for easy transferability to various computer makes. It has been developed on a supermicrocomputer (MC68000), however it has been adapted for IBM PC/XT or AT equipped with the DSI-32 co-processor card, and may be easily adapted for other computers, such as the VAX/VMS line of mini computers including the MICROVAX II, the SUN/2 and SUN/3 workstations, the HP 9000-500, the AT&T 7300 and Convergent Technology (MC 68010, MC 68020) line of super-micro and mini computers.

The code of STAN has a modular structure. Each of the modules is an independent program but all the modules share the STAN subroutine library. All data transfers between modules occur only via the data base. Diagram I.3 gives a schematic representation of the program structure.

At present, STAN is implemented for use on a wide variety of graphic terminals which include the Tektronix 4010, 4014, 4114, Visual 550 and all other Tektronix compatible monochrome terminals, as well as the Tektronix 4107, 4109, 4111, 4115, 4120, 4125 and the Seiko GR-1104 color graphic terminals. Any output displayed on the screen may be copied, if the terminal is equipped with a hard copy unit. The same output may be drawn with a high technical quality by using Calcomp, Hewlett Packard, Houston Instruments or Tektronix digital plotters.

STAN PROGRAM STRUCTURE

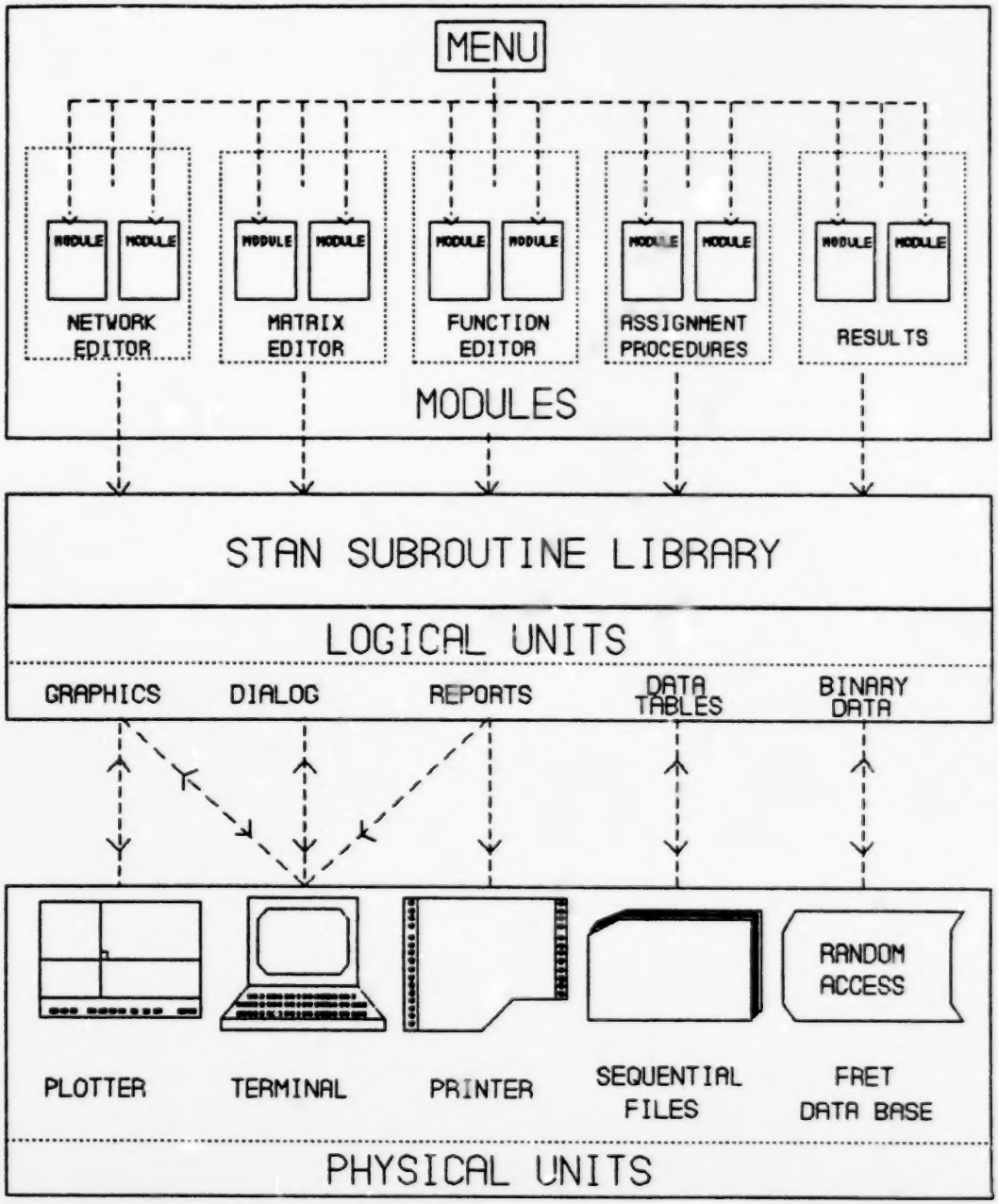


Diagram I.3

4. Some examples of STAN displays.

This section contains a sample of dialogs and outputs of STAN.

Figure 1 : The main menu which displays the STAN modules.

Figure 2 : Plot of the nodes of the network with demarcation lines.

Figure 3 : Selection of the window displayed in Figures 4 and 5.

Figure 4 : Plot of the subnetwork chosen in Figure 3. In this plot the modes are not identified, hence the plot is called "bare network".

Figure 5 : Plot of the subnetwork chosen in Figure 3. In this plot the modes are identified, hence the plot is called "base network". Ten modes are defined: *a, b, c, d, e* are rail modes with different gauges and power tractions (diesel, electric), *r* is the road mode, *p* is the port mode, *n* is internal navigation, *x* is import/export and *t* is coastal navigation.

Figure 6 : Selection of the window used in Figures 7 to 10.

Figure 7 : Plot of the subnetwork chosen in Figure 6, displaying the node numbers.

Figure 8 : Graphic worksheet used to modify interactively the base network. Note that node 2455 is incorrectly positioned.

Figure 9 : Using the options "Reg.nodes" and "Modify", node 2455 is moved away from the link that connects nodes 2456 and 2451.

Figure 10 : The plot is updated to display the modified network.

Figure 11 : Plot of transfers at node 1061.

Figure 12 : Graphic worksheet used to interactively add, delete or modify intermodal transfers (at node 1061).

Figure 13 : Examples of link and transfer delay functions and of the key words that may be used to define them.

```
User CRT_PIXL..J6 : Centre  de  Recherche sur les Transports
STAN Project:       B R A Z I L
Scen.1000(--- ---): R a i l ,  r o a d  a  ' p o r t  n e t w o r k s

1.  U T I L I T I E S

1.11 Direct data base manipulations
1.21 Log book consultation
1.22 Scenario manipulations
1.23 Input / modify / output utility data
1.31 Input          demarcation lines using batch entry
1.32 Input / modify demarcation lines interactively
1.34 Output         demarcation lines

2.  N E T W O R K  E D I T O R

2.01 Input / modify / output nodes
2.02 Input / modify / output products
2.11 Input          base network using batch entry
2.12 Input / modify base network interactively
2.13 Plot           base network
2.14 Output         base network
2.21 Input          transfers using batch entry
2.22 Input / modify transfers interactively
2.23 Plot           transfers
2.24 Output         transfers
2.33 Plot shortest paths on network

3.  M A T R I X  E D I T O R

3.01 Input / modify / display zone groups
3.11 Input          matrices using batch entry
3.12 Input / modify matrices interactively
3.13 Plot           matrices
3.14 Output         matrices
3.15 Plot           matrix histograms
3.25 Matrix calculations
3.26 Matrix balancing

4.  F U N C T I O N  E D I T O R

4.01 Input / modify / display function classes
4.11 Input          functions using batch entry
4.12 Input / modify functions interactively
4.13 Plot           functions
4.14 Output         functions

5.  A S S I G N M E N T  P R O C E D U R E S

5.11 Prepare scenario for  assignment
5.21 Multiproduct multimode assignment
5.31 Maxflow calculations

6.  R E S U L T S

6.01 Result summary
6.13 Plot    product costs and volumes
6.14 List    product results
6.15 Plot    product vehicles and convoys
6.23 Compare product costs and volumes
6.33 Plot    shortest paths on network

9.  E N D  O F  S E S S I O N
```

FIGURE 1

BARE NETWORK
STAN
LINK TYPES:
1 TO 899
WINDOW:
-25.96/-2.065
47.303/52.883
STAN PROJECT: BRAZIL
SCENARIO 1000: Rail, road and port networks
DATE: 87 02 16
MODULE: 2.13
CAT_PIXL....JG

FIGURE 2

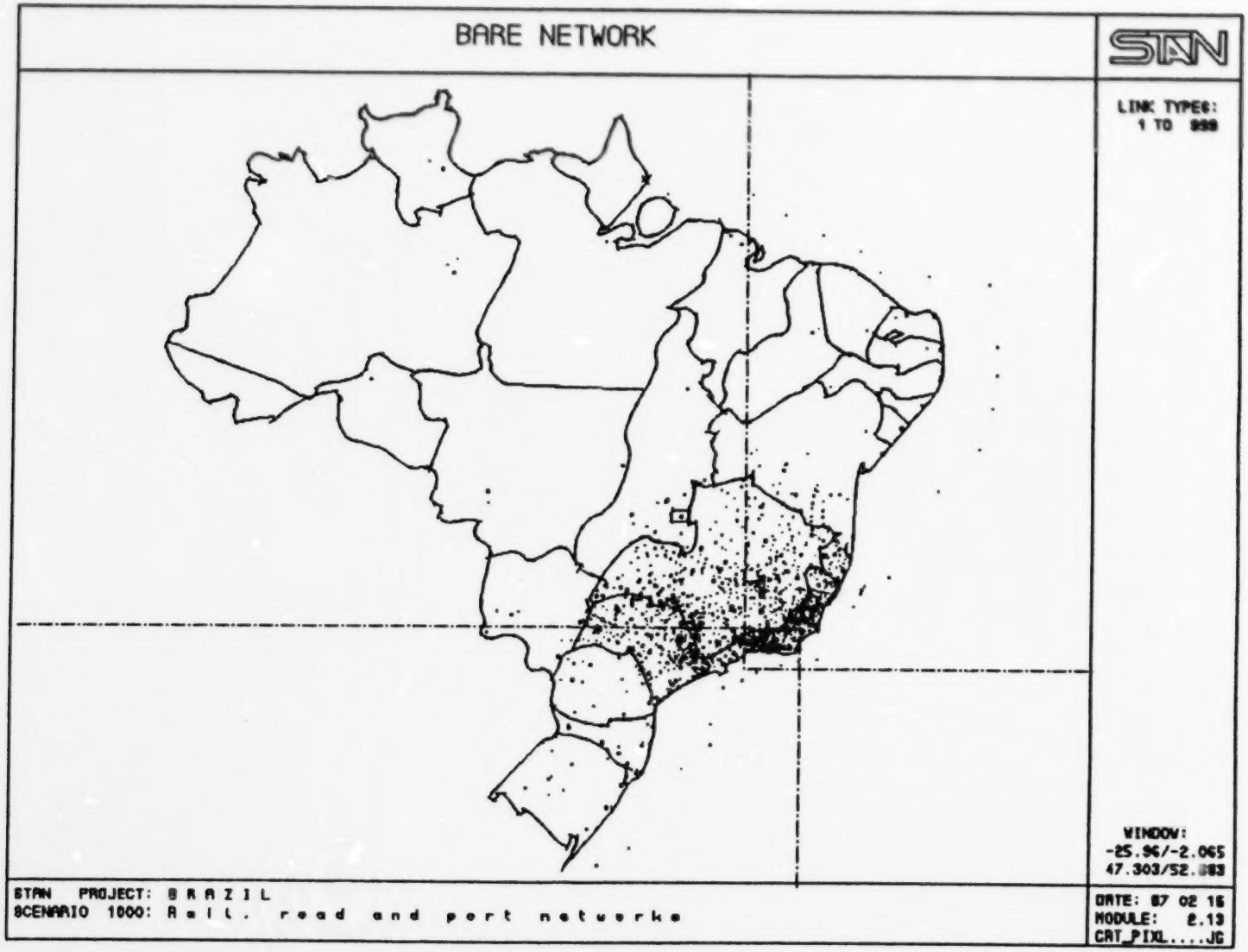

BARE NETWORK
STAN
LINK TYPES:
1 TO 999
WINDOW:
-25.96/-2.065
47.303/52.883
STAN PROJECT: BRAZIL
SCENARIO 1000: Rail, road and port networks
DATE: 87 02 15
MODULE: 2.13
CRT_PIXL....JG

FIGURE 3

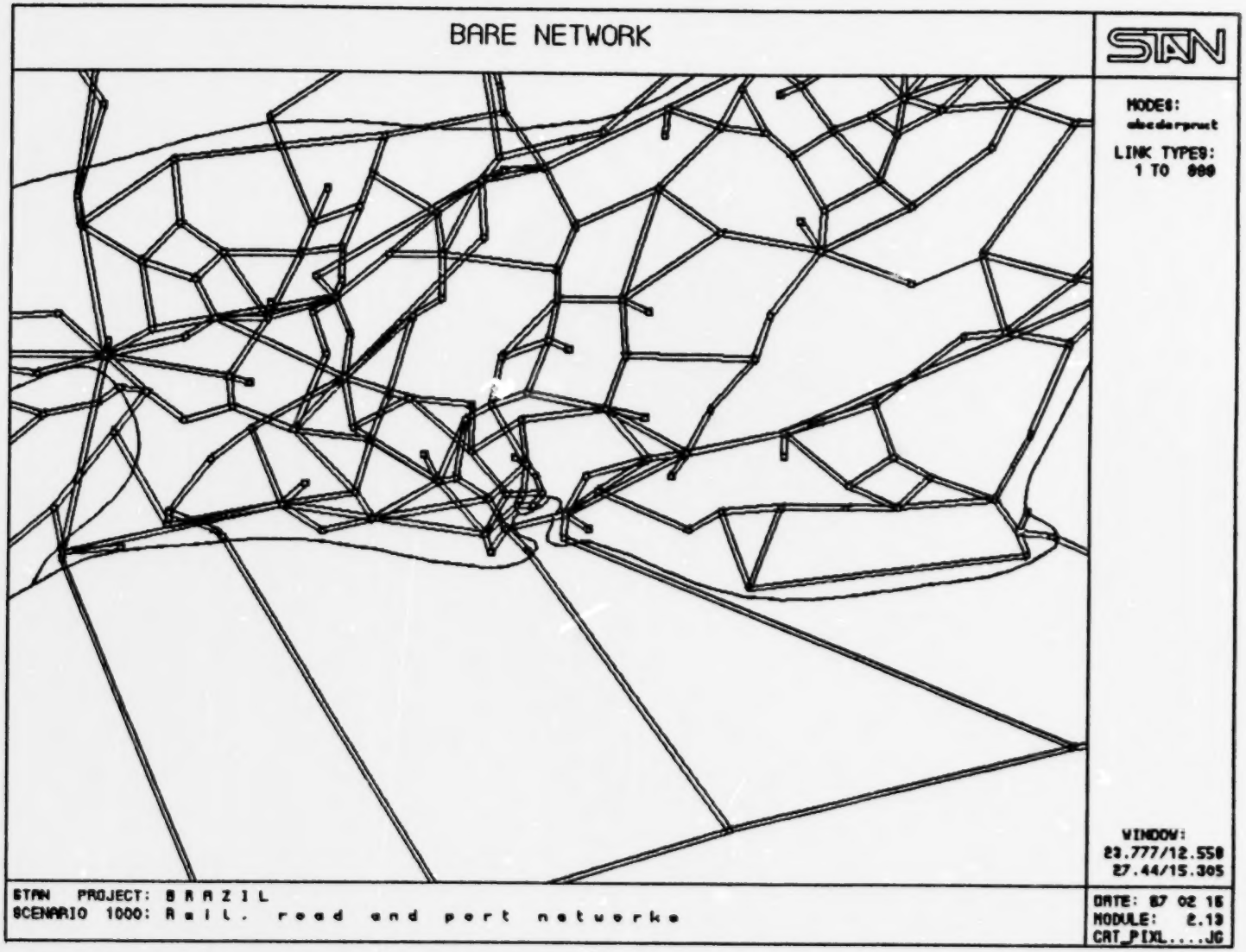

BARE NETWORK
STAN
MODES:
abcdefgprut
LINK TYPES:
1 TO 999
WINDOW:
23.777/12.550
27.44/15.305
STAN PROJECT: B R A Z I L
SCENARIO 1000: R a i l , r o a d a n d p o r t n e t w o r k s
DATE: 87 02 16
MODULE: 2.13
CRT_PIXL....JG

FIGURE 4

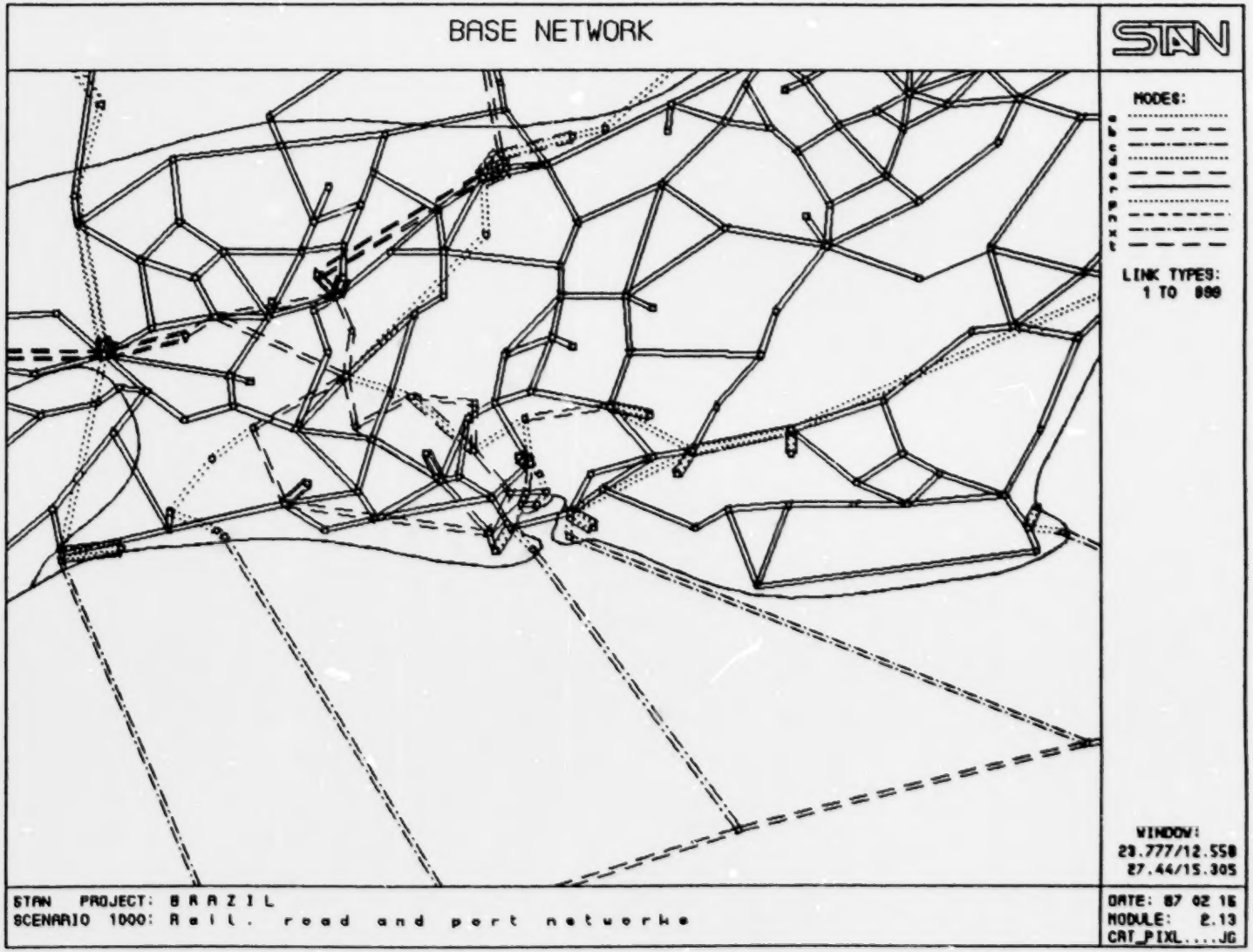

BASE NETWORK
STAN
MODES:
LINK TYPES:
1 TO 999
WINDOW:
23.777/12.558
27.44/15.305
STAN PROJECT: BRAZIL
SCENARIO 1000: Rail, road and port network
DATE: 87 02 16
MODULE: 2.13
CAT_PIXL....JG

FIGURE 5

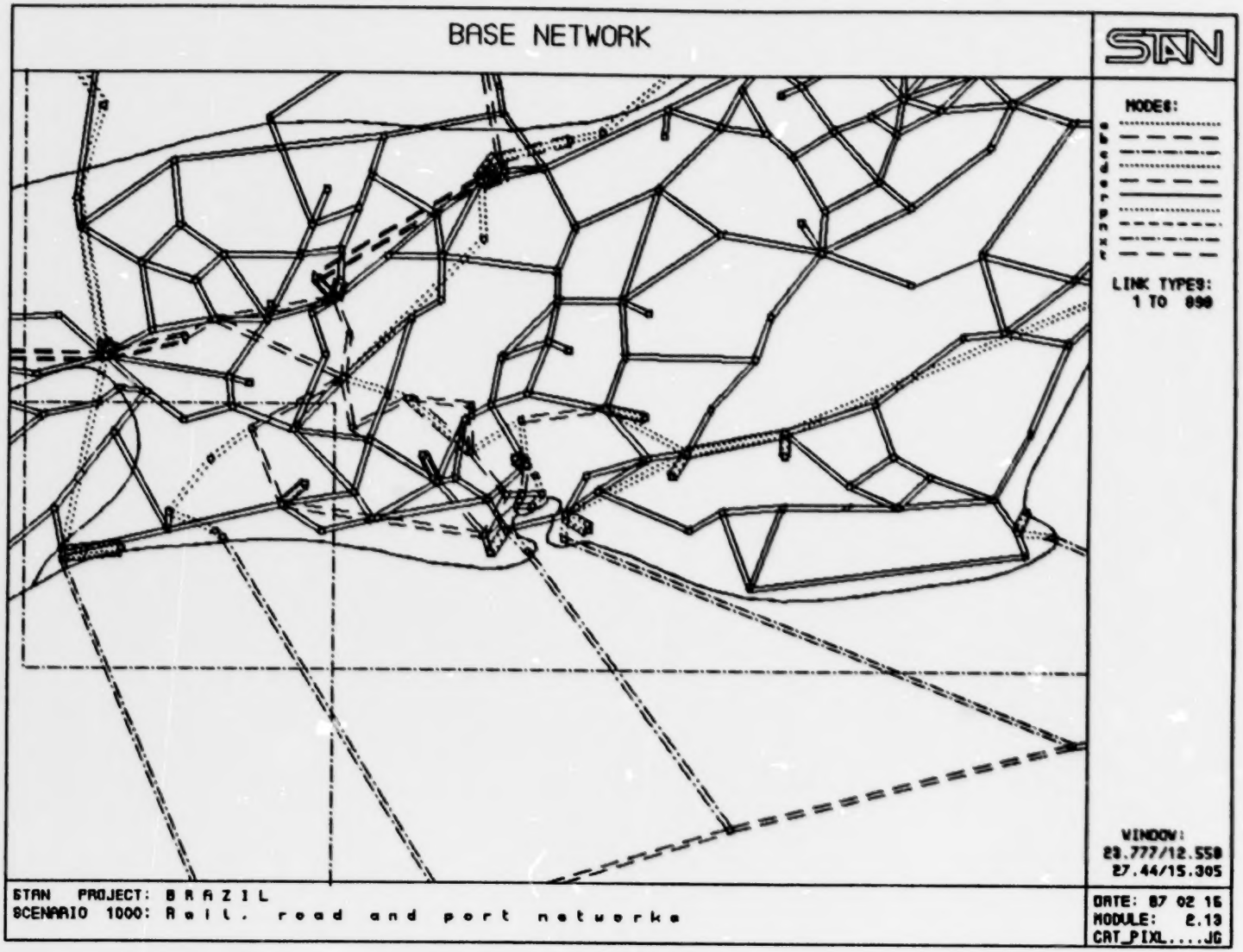

BASE NETWORK
STAN
MODES:
LINK TYPES:
1 TO 890
WINDOW:
23.777/12.558
27.44/15.305
STAN PROJECT: BRAZIL
SCENARIO 1000: Rail, road and port networks
DATE: 87 02 16
MODULE: 2.13
CRT_PIXL....JG

FIGURE 6

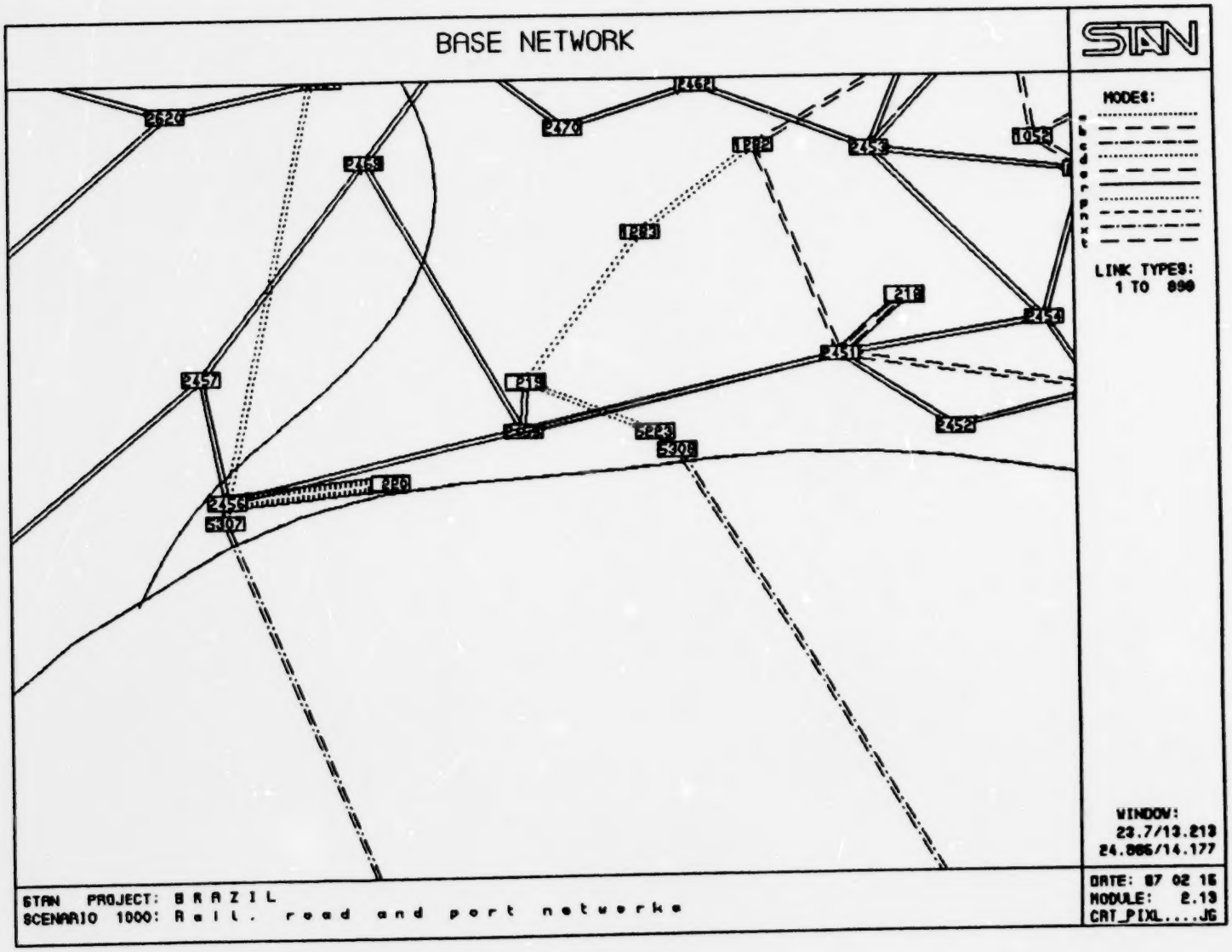

BASE NETWORK
STAN
MODES:
LINK TYPES:
1 TO 999
WINDOW:
23.7/13.213
24.885/14.177
STAN PROJECT: BRAZIL
SCENARIO 1000: Rail, road and port networks
DATE: 87 02 15
MODULE: 2.13
CAT_PIXL....JG

FIGURE 7

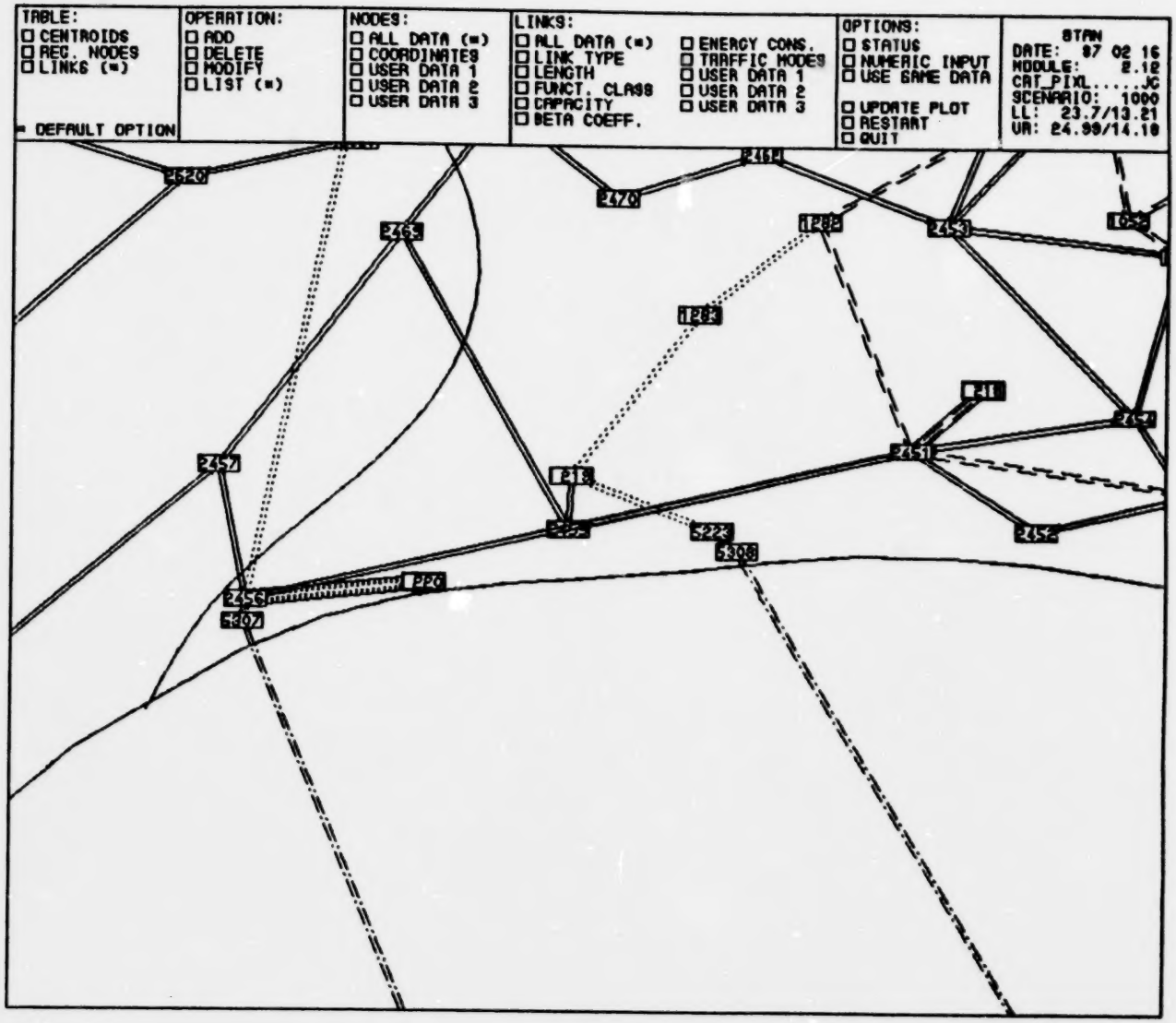
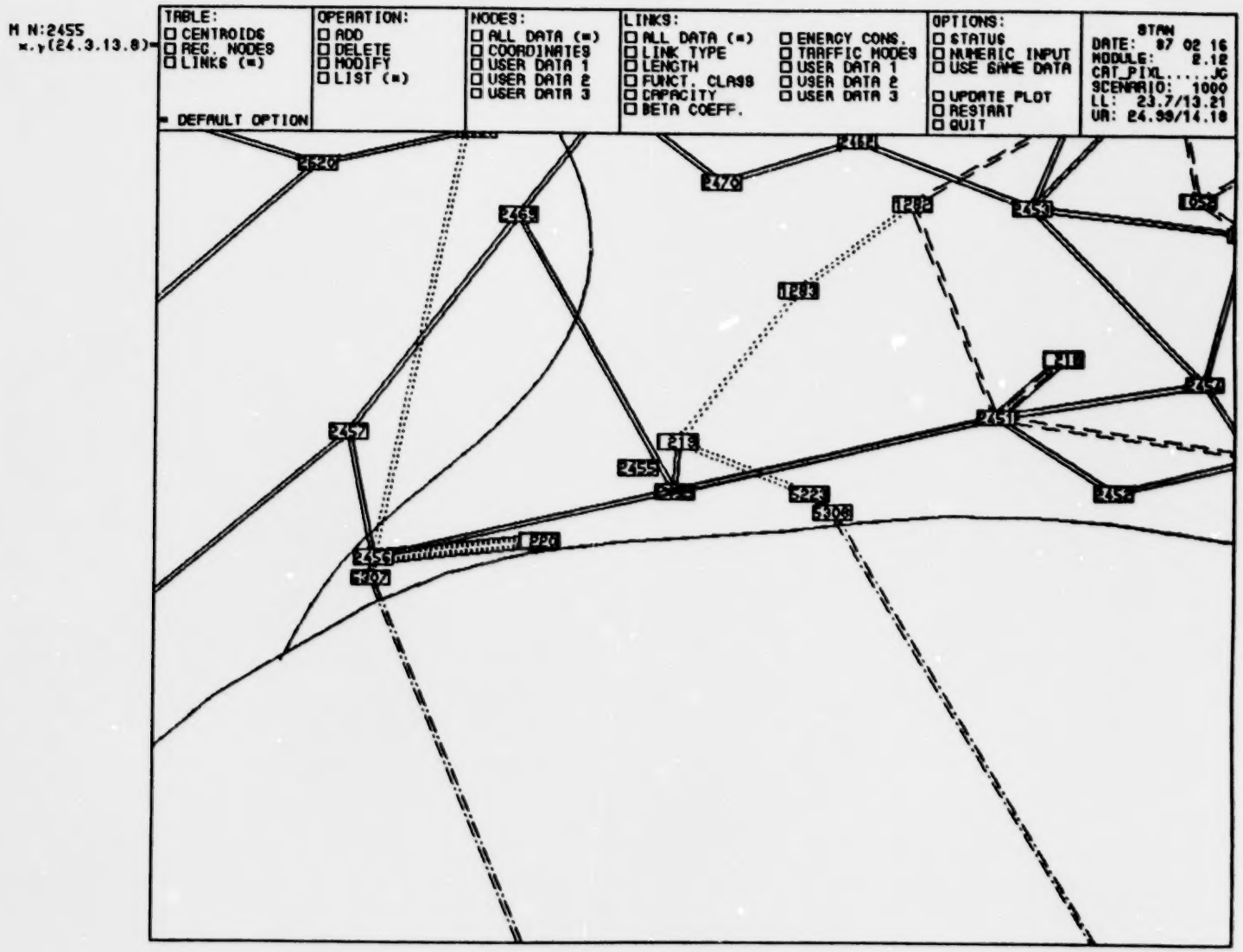


TABLE:
CENTROIDS
REG. NODES
LINKS (*)
* DEFAULT OPTION
OPERATION:
ADD
DELETE
MODIFY
LIST (*)
NODES:
ALL DATA (*)
COORDINATES
USER DATA 1
USER DATA 2
USER DATA 3
LINKS:
ALL DATA (*)
LINK TYPE
LENGTH
FUNCT. CLASS
CAPACITY
BETA COEFF.
ENERGY CONS.
TRAFFIC MODES
USER DATA 1
USER DATA 2
USER DATA 3
OPTIONS:
STATUS
NUMERIC INPUT
USE GAME DATA
UPDATE PLOT
RESTART
QUIT
STAN
DATE: 87 02 16
MODULE: 2.12
CAT_PIXL.....JC
SCENARIO: 1000
LL: 23.7/13.21
UR: 24.99/14.18
2620
2470
2462
2465
1283
2453
1283
41
2454
2452
2451
2457
5223
5305
2459
5207
220

FIGURE 8


M N:2455
x,y(24.3,13.8)
TABLE:
CENTROIDS
REC. NODES
LINKS (=)
= DEFAULT OPTION
OPERATION:
ADD
DELETE
MODIFY
LIST (=)
NODES:
ALL DATA (=)
COORDINATES
USER DATA 1
USER DATA 2
USER DATA 3
LINKS:
ALL DATA (=)
LINK TYPE
LENGTH
FUNCT. CLASS
CAPACITY
BETA COEFF.
ENERGY CONS.
TRAFFIC MODES
USER DATA 1
USER DATA 2
USER DATA 3
OPTIONS:
STATUS
NUMERIC INPUT
USE GAME DATA
UPDATE PLOT
RESTART
QUIT
STAN
DATE: 87 02 16
MODULE: 2.12
CAT_PIX.....JC
SCENARIO: 1000
LL: 23.7/13.21
UR: 24.99/14.18
2520
2476
2455
2457
2455
2307
2220
2451
2454
2454
2454

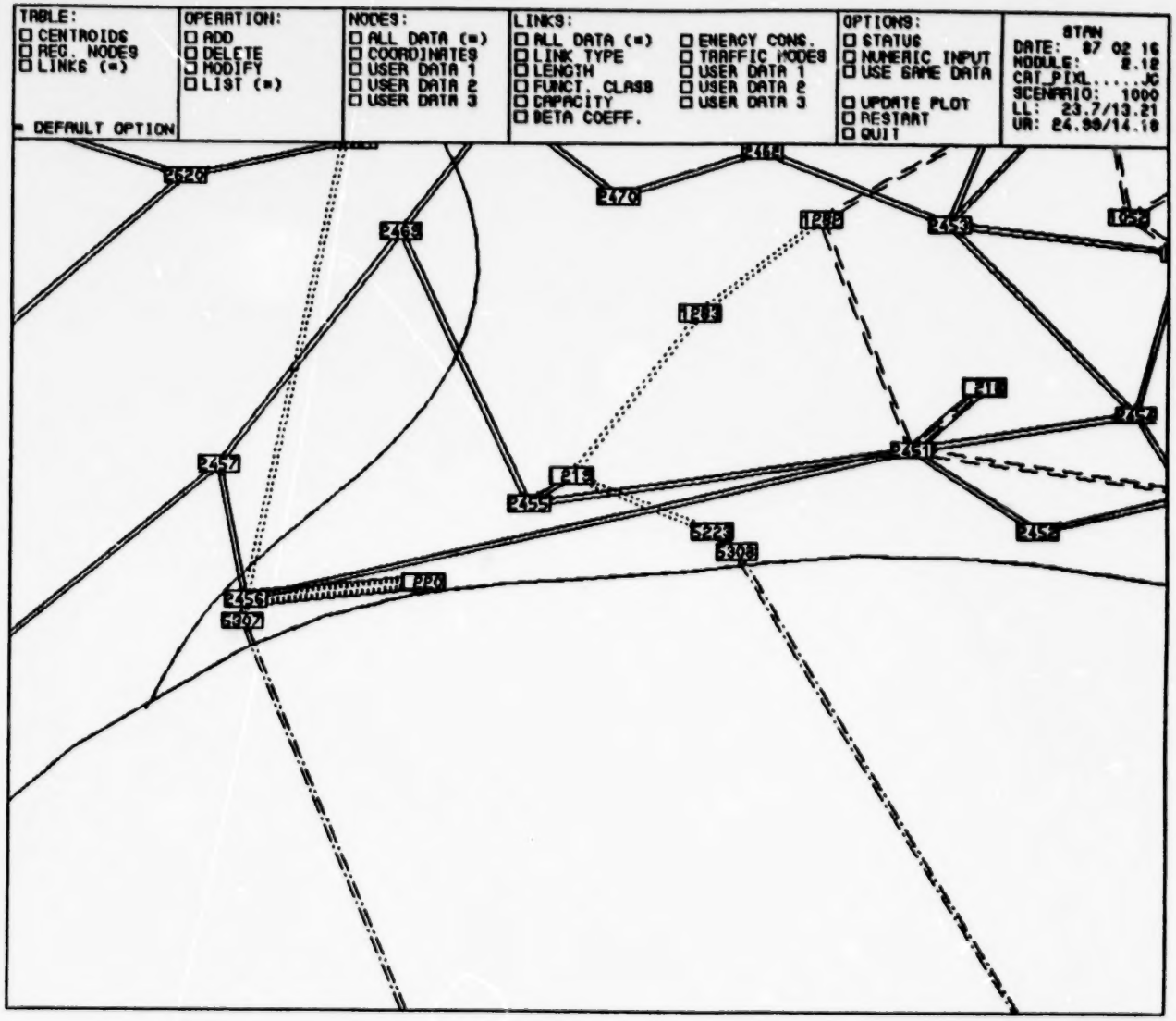


TABLE:
CENTROIDS
REG. NODES
LINKS (*)
* DEFAULT OPTION
OPERATION:
ADD
DELETE
MODIFY
LIST (*)
NODES:
ALL DATA (*)
COORDINATES
USER DATA 1
USER DATA 2
USER DATA 3
LINKS:
ALL DATA (*)
LINK TYPE
LENGTH
FUNCT. CLASS
CAPACITY
BETA COEFF.
ENERGY CONS.
TRAFFIC MODES
USER DATA 1
USER DATA 2
USER DATA 3
OPTIONS:
STATUS
NUMERIC INPUT
USE GAME DATA
UPDATE PLOT
RESTART
QUIT
STAN
DATE: 87 02 16
MODULE: 8.12
CAT_PIXL.....JC
SCENARIO: 1000
LL: 23.7/13.21
UR: 24.99/14.10
2620
2470
2468
2453
2457
2455
2451
5223
5308
5402

FIGURE 10

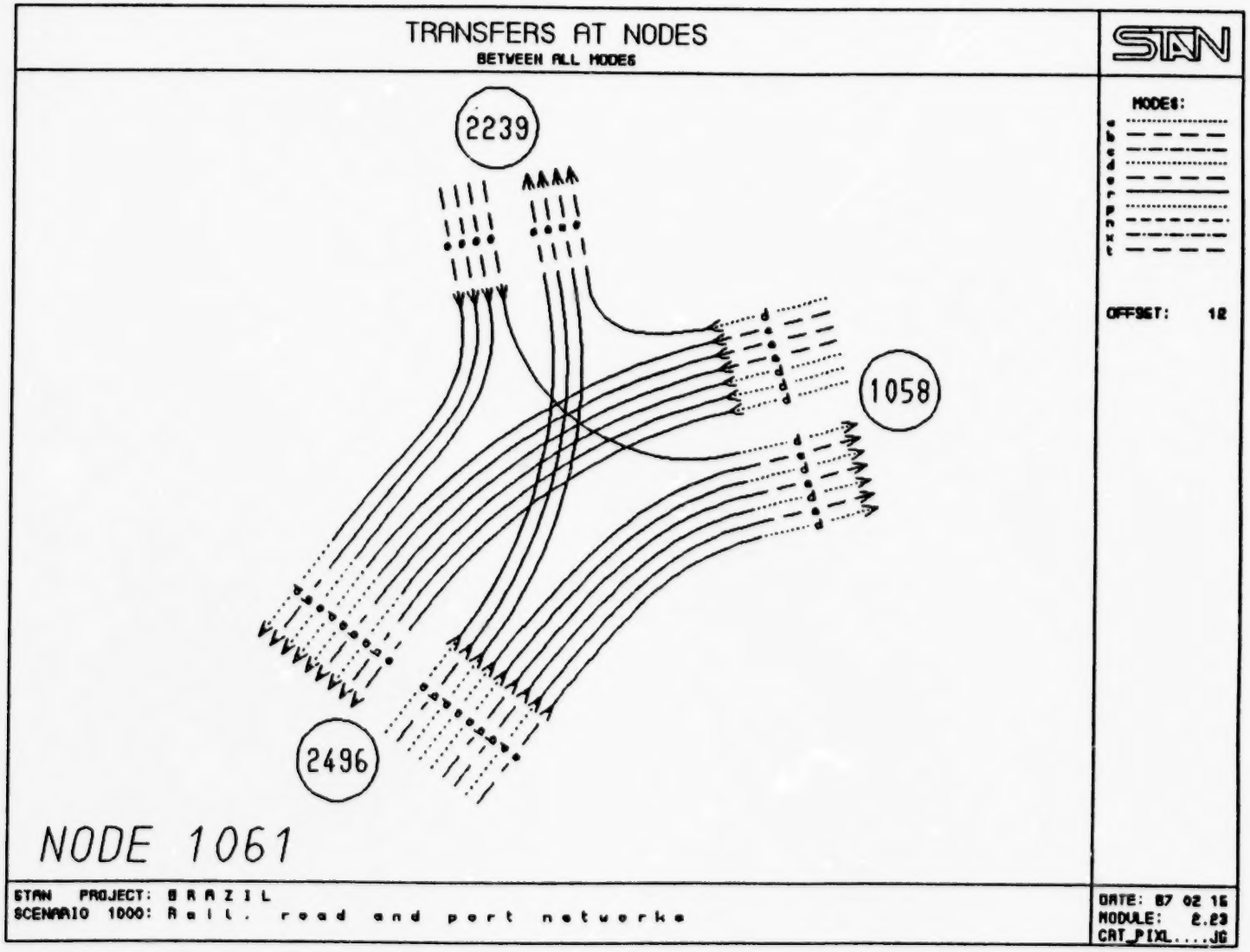

TRANSFERS AT NODES
BETWEEN ALL MODES
STAN
MODES:
OFFSET: 12
2239
1058
2496
NODE 1061
STAN PROJECT: BRAZIL
SCENARIO 1000: Rail, road and port networks
DATE: 87 02 15
MODULE: 2.23
CRT_PIXL....JG

FIGURE 11

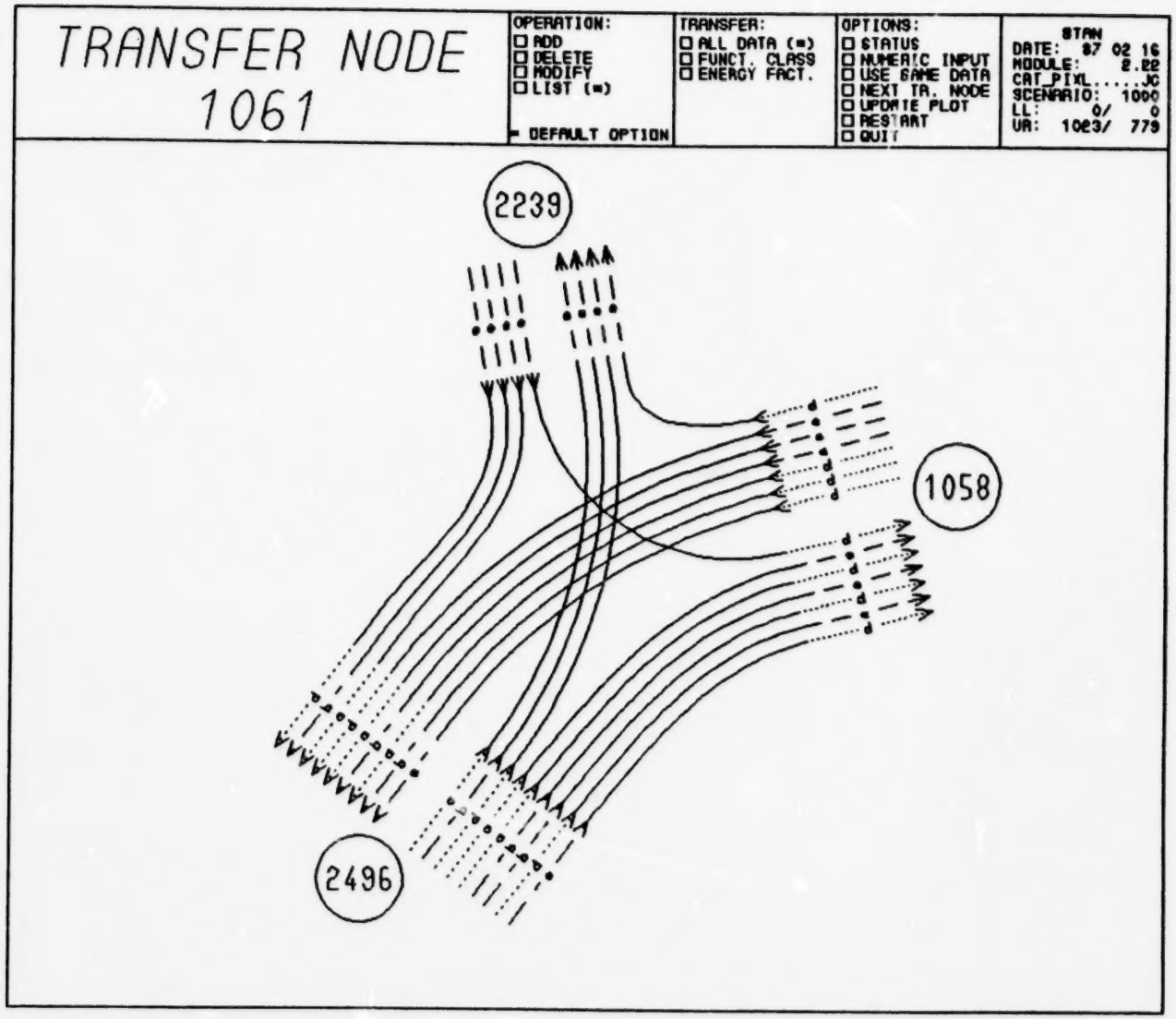

TRANSFER NODE
1061
OPERATION:
ADD
DELETE
MODIFY
LIST (=)
= DEFAULT OPTION
TRANSFER:
ALL DATA (=)
FUNCT. CLASS
ENERGY FACT.
OPTIONS:
STATUS
NUMERIC INPUT
USE GAME DATA
NEXT TR. NODE
UPDATE PLOT
RESTART
QUIT
STAN
DATE: 87 02 16
MODULE: 2.22
CAT_PIXL.....JC
SCENARIO: 1000
LL: 0/ 0
UR: 1023/ 779
2239
1058
2496

FIGURE 12

```
STAN  Module: 4.14        Date: 87 02 19          User: CRT_PIXL..J6          Page: 1773
Project:      B R A Z I L
-------------------------------------------------------------------------------------------

function definitions
--------------------


link delay                ( length   cap      beta     ul1      ul2      ul3      volprod
                            conwgt   wbyveh   vehwgt   up1      up2      up3      voltot
                            vehprod  vehtot   train    strain   um1      um2      um3
                            ump1     ump2     ump3 )

fdl1   = (.5 * ((1 + vehwgt / wbyveh) / (conwgt * beta)) + (ump2 /
          wbyveh) + up2 * (1 + vehwgt / wbyveh)) * .0181818 * length
         * (1 + .007857 * strain + 6.17999982 * ((strain / cap) ^ 6))


fdl2   = (.5 * ((1 + vehwgt / wbyveh) / (conwgt * beta)) + (ump2 /
          wbyveh) + up2 * (1 + vehwgt / wbyveh)) * .03333331 * length
          * (1 + .007857 * strain + 6.17999982 * ((strain / cap) ^ 6)
         )

fdl3   = (.5 * ((1 + vehwgt / wbyveh) / (conwgt * beta)) + (ump2 /
          wbyveh) + up2 * (1 + vehwgt / wbyveh)) * .025 * length * (1
          + .007857 * strain + 6.17999982 * ((strain / cap) ^ 6))

fdl4   = .0166666 * length

fdl5   = .03333331 * length

fdl6   = .10000001 * length

fdl7   = 1 + 5 * ((voltot / cap) ^ 4)

fdl8   = 2 + 5 * ((voltot / cap) ^ 4)

fdl9   = 1


transfer delay            ( volprod  voltot   up1      up2      up3      un1      un2
                            un3 )

fdt1   = .25 * (1 + up3)

fdt2   = 1 * (1 + up3)
```

FIGURE 13

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